PACKAGED MICROELECTRONIC IMAGERS AND METHODS OF PACKAGING MICROELECTRONIC IMAGERS

TECHNICAL FIELD

[0001] The present invention is related to microelectronic devices and methods for packaging microelectronic devices. Several aspects of the present invention are directed toward packaging microelectronic imagers that are responsive to radiation in the visible light spectrum or radiation in other spectrums.

BACKGROUND

[0002] Microelectronic imagers are used in digital cameras, wireless devices with picture capabilities, and many other applications. Cell phones and Personal Digital Assistants (PDAs), for example, incorporate microelectronic imagers for capturing and sending pictures. The use of microelectronic imagers in electronic devices has been steadily increasing as imagers become smaller and produce higher quality images with increased pixel counts.

[0003] Microelectronic imagers include image sensors that use Charged Coupled Device (CCD) systems, Complementary Metal-Oxide Semiconductor (CMOS) systems, or other systems. CCD image sensors have been widely used in digital cameras and other applications. CMOS image sensors are also becoming very popular because they have low production costs, high yields, and small sizes. CMOS image sensors provide these advantages because they are manufactured using technology and equipment developed for fabricating semiconductor devices. CMOS image sensors, as well as CCD image sensors, are accordingly "packaged" to protect their delicate components and provide external electrical contacts.

[0004] Figure 1 is a schematic view of a conventional microelectronic imager 1 with a conventional package. The imager 1 includes a die 10, an interposer substrate 20 attached to the die 10, and a housing 30 attached to the interposer substrate 20. The housing 30 surrounds the periphery of the die 10 and has an opening 32. The imager 1 also includes a transparent cover 40 over the die 10.

[0005] The die 10 includes an image sensor 12 and a plurality of bond-pads 14 electrically coupled to the image sensor 12. The interposer substrate 20 is typically a dielectric fixture having a plurality of bond-pads 22, a plurality of ball-pads 24, and traces 26 electrically coupling bond-pads 22 to corresponding ball-pads 24. The ball-pads 24 are arranged in an array for surface mounting the imager 1 to a board or module of another device. The bond-pads 14 on the die 10 are electrically coupled to the bond-pads 22 on the interposer substrate 20 by wire-bonds 28 to provide electrical pathways between the bond-pads 14 and the ball-pads 24.

[0006] The imager 1 shown in Figure 1 also has an optics unit including a support 50 attached to the housing 30 and a barrel 60 adjustably attached to the support 50. The support 50 can include internal threads 52, and the barrel 60 can include external threads 62 engaged with the threads 52. The optics unit also includes a lens 70 carried by the barrel 60.

[0007] One problem with conventional packaged microelectronic imagers is that they have relatively large footprints and occupy a significant amount of vertical space (i.e., high profiles). For example, the footprint of the imager 1 in Figure 1 is the surface area of the bottom of the interposer substrate 20, which is significantly larger than the surface area of the die 10. Accordingly, the footprint of conventional packaged microelectronic imagers can be a limiting factor in the design and marketability of picture cell phones or PDAs because these devices are continually shrinking to be more portable. Therefore, there is a need to provide microelectronic imagers with smaller footprints and lower vertical profiles.

[0008] Another problem with conventional microelectronic imagers is the manufacturing costs for packaging the dies. The housing 30 shown in Figure 1 is relatively expensive to form and mount because the transparent cover 40 must be

properly aligned and mounted in the opening 32 and then the housing 30 must be positioned and mounted to the interposer substrate 20. This process can be subject to error and is generally time-consuming. Moreover, forming the wire-bonds 28 on the imager 1 shown in Figure 1 is complex and expensive because it requires connecting an individual wire between each bond-pad 14 on the die 10 and a corresponding interior pad 22 on the interposer substrate 20. In addition, it may not be feasible to form wire-bonds for the high-density, fine-pitch arrays of some high-performance devices. Therefore, there is a significant need to enhance the efficiency and reliability of packaging microelectronic imagers.

[0009] Yet another problem of the conventional imager 1 shown in Figure 1 is that moisture and/or other contaminants can impair the performance of the imager 1. Even though the die 10 is packaged within a cell formed by interposer substrate 20, housing 30 and cover 40, moisture or other contaminants can get into the cell. For example, the seals of the substrate/housing and the housing/cover interfaces can fail because of faulty materials or assembly. The seals at these interfaces can also fail because the different coefficients of thermal expansion between the substrate 20, housing 30 and cover 40 induce strain at the interfaces that can break the seals. Moisture may also be stored in the substrate 20 and expelled into the cell at elevated temperatures. This is more likely with substrates formed from organic materials. Therefore, there is also a need to improve the integrity of the package to enhance the protection of the image sensor.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Figure 1 is a schematic side cross-sectional view of a packaged microelectronic imager in accordance with the prior art.

[0011] Figure 2A is a schematic side cross-sectional view of a microelectronic imager in accordance with an embodiment of the invention.

[0012] Figure 2B is a bottom isometric view including a cut-out portion of a cover unit for use with the imager of Figure 2A.

[0013] Figure 3 is a schematic side cross-sectional view of a microelectronic imager in accordance with another embodiment of the invention.

[0014] Figure 4 is a schematic side cross-sectional view of a microelectronic imager in accordance with another embodiment of the invention.

[0015] Figure 5 is a schematic side cross-sectional view of a microelectronic imager in accordance with another embodiment of the invention.

[0016] Figure 6 is a schematic side cross-sectional view of a microelectronic imager in accordance with another embodiment of the invention.

[0017] Figure 7 is a schematic side cross-sectional view of a plurality of microelectronic imagers formed on a microfeature workpiece in accordance with another embodiment of the invention.

[0018] Figure 8 is a schematic side cross-sectional view of a microelectronic imager in accordance with another embodiment of the invention.

DETAILED DESCRIPTION

A. Overview

[0019] The following disclosure describes several embodiments of microelectronic imagers and methods of packaging microelectronic imagers. One particular embodiment of the invention is directed toward a microelectronic imaging unit comprising a microelectronic die, an integrated circuit, and an image sensor electrically coupled to the integrated circuit. The imaging die also includes a plurality of electrical terminals, such as bond-pads, electrically coupled to the integrated circuit. The imaging unit further includes a cover unit having a side member attached to the die. The cover unit includes a window carried by the side member such that the window is located at a desired location relative to the image sensor.

[0020] The cover unit can have several different configurations. In one embodiment, for example, the cover unit is a single unitary member that is attached to the die. The window and side member are accordingly integral with each other in such an embodiment. The cover unit, however, can be made of separate components in which the window is attached to the side member. The window and side member can accordingly be made from different materials in such embodiments. The cover unit can be pre-assembled before it is attached to

the microelectronic die. The entire cover unit can be made of glass, quartz, or other materials transmissive to a desired spectrum of radiation. In embodiments directed toward imaging radiation in the visible spectrum, the cover unit can also filter infrared radiation or other undesirable spectrums of radiation.

[0021] In another aspect of the invention, an optics unit can be attached to the cover unit. The optics unit can include a stand-off or support member and an optic member carried by the support member. The support member can be attached to the cover unit and configured to position the optic member at a desired location relative to the image sensor. In other embodiments, the cover unit has an optic member in addition to or in lieu of having a separate optics unit.

[0022] Another aspect of the invention is directed to methods of packaging microelectronic imagers. One embodiment of such a method includes providing a microelectronic die having an image sensor, an integrated circuit electrically coupled to the image sensor, and a plurality of electrical terminals electrically coupled to the integrated circuit. The method further includes providing a cover unit having a side member and window carried by the side member. A plurality of electrically conductive interconnects aligned with corresponding bond-pads are formed through the microelectronic die and/or the cover unit. The method also includes attaching the cover unit to the die with the window positioned at a desired location relative to the image sensor. The method can also include attaching an optics unit having an optic member to the cover unit with the optic member positioned at a desired location relative to the image sensor.

[0023] Specific details of several embodiments of the invention are described below with reference to CMOS imagers to provide a thorough understanding of these embodiments, but other embodiments can be CCD imagers or other types of imaging devices. Several details describing well-known structures often associated with microelectronic devices are not set forth in the following description to avoid unnecessarily obscuring the description of the disclosed embodiments. Additionally, several other embodiments of the invention can have different configurations and/or components than those described in this section. As such, a person of ordinary skill in the art will accordingly understand that the

invention may have other embodiments with additional elements or without several of the elements shown and described below with reference to Figures 2A-8.

B. Embodiments of Microelectronic Imagers

[0024] Figure 2A is a schematic side cross-sectional view of a microelectronic imager 200 in accordance with one embodiment of the invention. In the illustrated embodiment, the microelectronic imager 200 includes an imaging unit 130 and an optics unit 150. The embodiment of the imaging unit 150 shown in Figure 2A includes a die 210 having a first side 211, a second side 212 opposite the first side 211, and a plurality of end surfaces 213 defining a perimeter of the die 210. The die 210 includes an integrated circuit 215 (shown schematically), an image sensor 216 operably coupled to the integrated circuit 215, and a plurality of terminals 222 (e.g., bond-pads) electrically coupled to the integrated circuit 215. The image sensor 216 can be a CMOS device or CCD for capturing pictures or other images in the visible spectrum. In other embodiments, the image sensor 216 can detect radiation and other spectrums (e.g., IR or UV ranges).

[0025] The microelectronic imager 200 can further include a cover unit 260. Figure 2B is a partially schematic isometric view of the cover unit 260. Referring to Figures 2A and 2B together, the cover unit 260 includes a window 263 with a first side 261 facing generally away from the image sensor 216 and a second side 262 facing generally toward the image sensor 216. The cover unit 260 can be made of glass, quartz, or other materials transmissive to a desired spectrum of radiation. In embodiments directed toward imaging radiation in the visible spectrum, the cover unit 260 can also filter infrared radiation or other undesirable spectrums of radiation. The cover unit 260, for example, can be formed from a material and/or can have a coating that filters IR or near IR spectrums, and the cover unit 260 can have an anti-reflective (AR) coating. In some embodiments, a single coating can filter the desired spectrum and provide the desired anti-reflective properties.

[0026] The cover unit 260 can further include a side member 264. The side member 264 projects from the cover unit 260 and is configured to engage corresponding end surfaces 213 of the die 210. The side member 264 can further include a first interface feature 265 having a first stop component 266. The first

stop component 266 provides a fixed surface at a known distance from the image sensor 216 for accurately positioning the cover unit 260, and more particularly the window 263, at a desired focus distance with respect to the image sensor 216. The first stop component 266 of the first interface feature 265 engages and mates with a corresponding portion of the die 210 to fixedly attach the cover unit 260 to the die 210. In this embodiment, the first interface feature 265 also includes a perimeter sidewall 270 that surrounds the end surfaces 213 defining the perimeter of the die 210. In some embodiments, an epoxy (not shown) can be used along the first stop component 266 and the sidewall 270 of the side member 264 to attach the cover unit 260 to the die 210. In other embodiments, other adhesive materials can be used to secure the cover unit 260 to the die 210 or, alternatively, no adhesive materials may be used. Additionally, the interface member 265 can include other types of features, or the side member 264 may not include an interface feature.

[0027] Referring back to Figure 2A, this embodiment of the microelectronic imager 200 further includes a plurality of interconnects 226 having a first portion electrically coupled to corresponding bond-pads 222 and a second portion electrically coupled to a plurality of corresponding ball-pads 224. In the embodiment shown in Figure 2A, the interconnects 226 are through-wafer interconnects that extend from the first side 211 to the second side 212 of the die 210 and contact corresponding bond-pads 222. Alternatively, other microelectronic imagers may not include through-wafer type interconnects 226. The interconnects 226 can be formed according to the processes disclosed in U.S. patent application number 10/713,878, entitled "Microelectronic Devices, Methods for Forming Vias in Microelectronic Devices, and Methods for Packaging Microelectronic Devices," filed on November 13, 2003 (Perkins Coie Docket No. 108298742US), which is incorporated by reference herein. The ball-pads 224 are formed in and/or on the second side 212 of the die 210 and are configured to receive solder balls 227 or other conductive elements. In other embodiments, the microelectronic imager 200 may not include the ball-pads 224 and/or the solder balls 227.

[0028] In the illustrated embodiment, the optics unit 150 of the microelectronic imager 200 is mounted to the cover unit 260. The optics unit 150 can include a plate 252 and an optic member 254 on the plate 252. The optic member 254 can be a lens for focusing the light, pinholes for reducing higher order refractions, and/or other optical structures for performing other functions.

[0029] The imager 200 further includes a stand-off or support member 240 between the imaging unit 130 and the optics unit 150. The embodiment of the support member 240 shown in Figure 2A further includes a first referencing element 232 attached to the first side 261 of the cover unit 260 at a fixed position relative to the image sensor 216 and a second referencing element 242 that carries the plate 252 and the optic member 254. The support member 240 accurately situates the optic member 254 at a desired location with respect to the image sensor 216. Suitable support members 240 with additional interface features are disclosed in U.S. Application No. 10/723,363, entitled "Packaged Microelectronic Imagers and Methods of Packaging Microelectronic Imagers," filed on November 26, 2003 (Perkins Coie Docket No. 108298746US), which is herein incorporated by reference. The plate 252 is attached to the support member 240 in the embodiment shown in Figure 2A, but other embodiments of the optics unit 150 may not include a plate such that the optic member 254 is attached directly to the support member 240.

[0030] The cover unit 260 shown in Figures 2A and 2B has several advantages compared to conventional imagers with separate housings, interposer substrates and dies. One advantage is that the cover unit 260 provides good protection for the die 210 because the cover unit 260 is a single, unitary component in which the window 263 and the side member 264 are integral with each other. The die 210 typically has six areas (e.g., sides) to seal and protect (i.e., the first side 211, the four end surfaces 213 defining the perimeter of the die 210, and the second side 212). The cover unit 260 inherently provides protection for five of the six sides (i.e., the first side 211 and the four end surfaces 213). Therefore, only a single seal is necessary along the second side 212 of the die 210. Another advantage of this feature is that the cover unit 260 is a more robust package and has fewer

failure points. This feature helps prevent contamination or possible damage to the components of the die 210 during handling to enhance the protection of the die 210.

[0031] Another advantage of the cover unit 260 illustrated in Figures 2A and 2B is that there is no need for additional spacers or support members to support the cover unit 260 over the die 210. Accordingly, the manufacturing process can be more efficient because there is no need for additional steps or processes to construct spacer elements to the first side 211 of the die 210 or mount a separate housing to an interposer substrate. Further, the first interface features 265 on the cover unit 260 provide very precise control of the stand-off distance for the window 263 of the cover unit 260 with respect to the image sensor 216.

[0032] Another feature of the microelectronic imager 200 illustrated in Figure 2A is that the microelectronic imager 200 can be much smaller than the conventional imager shown in Figure 1. The footprint of the microelectronic imager 200 can be nearly as small as the size of the die 210 because the die is not mounted to a separate interposer substrate. This is possible because the interconnects 226 provide an electrical connection to an array of ball-pads 224 on the second side 212 of the die 210 instead of using wire-bonds on the first side 211 of the die 210. The height of the microelectronic imager 200 is also less than with conventional imagers because the imager 200 can be mounted directly to a module or board without an interposer substrate. Therefore, the microelectronic imager 200 is expected to have a smaller footprint and a lower profile than conventional microelectronic imagers, which is particularly advantageous for picture cell phones, PDAs, or other applications where space is limited.

[0033] Figure 3 is a schematic side cross-sectional view of a microelectronic imager 300 in accordance with another embodiment of the invention. The microelectronic imager 300 can be generally similar to the microelectronic imager 200 shown in Figure 2A; like reference numbers accordingly refer to like components in Figures 2A and 3. In this embodiment, the imager 300 has a cover unit 360 that includes a window 363 (e.g., a cover) and a side member 364. The side member 364 is attached to the window 363 before the cover unit 360 is

attached to the die 210. The primary difference between the cover unit 360 shown in Figure 3 and the cover unit 260 shown in Figure 2A is that the window 363 is not formed integrally with the side member 364. The window 363 and side member 364 in this embodiment are accordingly separate components that can be made from the same material or different materials. For example, the window 363 can be made of glass, quartz, or other materials transmissive to a desired spectrum of radiation, and the side member 364 can be made of a different material. The side member 364 conforms to the end surfaces 213 of the die 210 to position the window 363 at a desired location relative to the image sensor 216.

[0034] Figure 4 is a schematic side cross-sectional view of a microelectronic imager 400 in accordance with another embodiment of the invention. In one aspect of this embodiment, the microelectronic imager 400 can include a cover unit 460 that combines certain features of the cover unit 260, support member 240 and optic member 254 described above with reference to Figure 2A to form an integrated cover/optics unit. The cover unit 460 includes a window 463 having a first side 461 facing generally away from the image sensor 216 and a second side 462 facing generally toward the image sensor 216. The cover unit 460 further includes a side member 464 with alignment features corresponding to end surfaces 213 of the die 210. The side member 464 can be attached to the die 210 as described above with reference to Figure 2A. The cover unit 460 can also include an optic member 454 attached to or formed integrally with the window 463. The side member 464 can be configured to position the optic member 454 at a desired location relative to the image sensor 216. In one aspect of this embodiment, the optic member 454 is part of the single unitary component type cover unit 460 and can be formed of the same material as the cover unit 460. In other embodiments, the optic member 454 can be attached separately to the single unitary member cover unit 460 and can be made of other materials.

[0035] Figure 5 is a schematic side cross-sectional view of a microelectronic imager 500 in accordance with another embodiment of the invention. In one aspect of this embodiment, the microelectronic imager 500 can include a microelectronic die 510 generally similar to the microelectronic die described

above with respect to Figure 2. The die 510 includes a first side 511, a second side 512 opposite the first side 511, and a plurality of end surfaces 513 defining the perimeter of the die 510. The die 510 includes an integrated circuit 515 (shown schematically), an image sensor 516 operably coupled to the integrated circuit 515, and an array of terminals 522 (e.g., bond-pads) electrically coupled to the integrated circuit 515. The die 510 differs from the die 210 shown in Figure 2 in that the die 510 does not have through-wafer interconnects extending from the bond-pads 522 to the second side 512 of the die 510.

[0036] The microelectronic imager 500 can further include a cover unit 560 having a window 563 with a first side 561 facing generally away from the image sensor 516 and a second side 562 facing generally toward the image sensor 516. The cover unit 560 can further include a side member 564. The side member 564 projects from the window 563 and is configured to conform to the end surfaces 513 defining the perimeter of the die 510. The side member 564 can be attached to the end surfaces 513 of the die 510 as described above with respect to Figure 2. In a further aspect of this embodiment, an encapsulant 575 can be disposed on the second side 512 of the die 510 to protect the die 510 from contamination and possible damage during handling. The encapsulant 575 can be applied using processes and methods known to those of skill in the art.

[0037] The cover unit 560 can further include a plurality of interconnects 526 electrically coupled to corresponding bond-pads 522 and extending through the cover unit 560. The interconnects 526 are generally constructed through the cover unit 560 before the cover unit 560 is attached to the die 510, but it is conceivable that they could be formed afterwards. The interconnects 526 shown in Figure 5 are in electrical contact with corresponding ball-pads 524 or other external contacts. The pads 524 provide external electrical contacts for the die 510 arranged in a front side array for solder balls (not shown) or other conductive elements.

[0038] In another aspect of the embodiment illustrated in Figure 5, the microelectronic imager 500 can further include an optics unit 550 attached to the cover unit 560 and aligned with the image sensor 516. The optics unit 550 can

include a substrate 552 and an optic member 554 on the substrate 552 to transmit at least the desired spectrum of radiation to the image sensor 516. The substrate 552 and optic member 554 are supported by a support member 540. The optic member 554 can be a lens for focusing the light, a pinhole for reducing higher order refractions, and/or other optical structures for performing other functions. In further embodiments, the microelectronic imager 500 may not include an optics unit 550 or the optics unit 550 can have a different configuration.

[0039] Figure 6 is a schematic side cross-sectional view of a microelectronic imager 600 in accordance with another embodiment of the invention. In one aspect of this embodiment, the microelectronic imager 600 can include a microelectronic die 510 generally similar to the microelectronic die described above with respect to Figure 5; like reference numbers refer to like components in Figures 5 and 6. The microelectronic imager 600 can further include a cover unit 660 having a window 663 with a first side 661 facing generally away from the image sensor 516 and a second side 662 facing generally toward the image sensor 516. The cover unit 660 further includes a side member 664 having a sealing face 665 attached to the first side 511 of the die 510. The side member 664, however, differs from the previously described side members in Figures 2A-5 in that the side member 663 does not engage nor otherwise surrounds the end surfaces 513 of the die 510. In some embodiments, an adhesive (not shown) can be used to secure the cover unit 660 to the die 510. In a further aspect of this embodiment, an encapsulant 675 can be disposed on a second side 512 of the die 510 and over the end surfaces 513. The encapsulant 675 can also coat at least a portion of the cover unit 660. The encapsulant 675 seals and protects the die 510 and cover unit 660 from contamination and possible damage during handling. The encapsulant 675 can be applied using processes and methods known to those of skill in the art.

[0040] The cover unit 660 can also include a plurality of electrically conductive interconnects 626 electrically coupled to corresponding bond-pads 522 on the die 510 and extending through the cover unit 660. The interconnects 626 can be generally similar to the interconnects 526 described above with respect to Figure

5. In another aspect of the embodiment illustrated in Figure 6, the microelectronic imager 600 can further include the optics unit 550 attached to the cover unit 660 and aligned with the image sensor 516.

[0041] One feature of the illustrated embodiment is that side member 664 of the cover unit 660 does not have an interface element that is juxtaposed to the end surfaces 513 of the die 510. An advantage of this feature is that the footprint of the microelectronic imager 600 can be smaller than that of microelectronic imagers that include cover units with a side member surrounding the end surfaces 513 of the die 510. This is particularly advantageous for picture cell phones, PDAs, and other applications where space is limited.

[0042] Figure 7 is a schematic side cross-sectional view of an assembly 700 including a plurality of microelectronic imagers 701 that each have an imaging unit and an optics unit. The assembly 700 includes a microfeature workpiece 702 having a first substrate 704 and a plurality of microelectronic dies 210 formed in and/or on the first substrate 704. The individual microelectronic dies 210 can be generally similar to the dies described above with respect to Figures 2A and 3. The assembly 700 further includes a second substrate 705 having a plurality of cover units 760. The individual cover units 760 can be generally similar to the cover units described above with respect to Figures 2A and 2B. The individual cover units 760 can also include a first referencing element 732.

[0043] An optics workpiece 706 can include a third substrate 707 and a plurality of optics units 750. Individual optics units 750 can be generally similar to the optics units described above with respect to Figures 2A and 3. The individual optics units 750 can be attached to or otherwise include support members 742. As explained above, the support members 742 can have first and second referencing elements configured to be keyed together or otherwise seated with each other in a manner that aligns individual optic members 254 with corresponding image sensors 216.

[0044] The imagers 701 can be assembled by (a) attaching the second substrate 705 with the cover units 760 to the third substrate 707 with corresponding optics units 750, (b) cutting the substrate 702 along lines A-A to singulate the individual

dies 210, (c) attaching individual dies 210 to corresponding cover units, and (d) cutting substrates 705 and 707 along lines A-A to separate individual imagers from each other. In a different embodiment, the individual imager components (e.g., optic units, cover units, and dies) can each be singulated and individual imagers can be assembled from the singulated components. In still other embodiments, the imagers can be assembled using various combinations of the above assembly steps.

[0045] From the foregoing, it will be appreciated that specific embodiments of the invention have been described herein for purposes of illustration, but that various modifications may be made without deviating from the spirit and scope of the invention. For example, the microelectronic imager may not include electrically conductive interconnects extending through the cover unit or, alternatively, may not include interconnects at all. Furthermore, various aspects of any of the foregoing embodiments can be combined in different combinations. Figure 8, for example, illustrates a microelectronic imager 800 that is a combination of the imaging unit 200 from Figure 2A and the cover unit 560 from Figure 5. Accordingly, the invention is not limited except as by the appended claims.